



# 2011 Disability Research State of the Science Conference

*Assistive Technology/Technology Forum*  
*Breakout Session “Accessible Fitness Equipment: Where Are We?  
Where Do We Go? Facilitating Maximum Involvement”*

*How Might NASA Exercise Research and Technology Help Individuals  
With Disabilities?*  
*Facilitating Knowledge Transfer*

**Arlington, Virginia**  
**July 13, 2011**

**David L. Tomko, Ph.D.**  
**Program Executive for Human Research Program and Fundamental Space Biology**  
**Advanced Capabilities Division**  
**Exploration Systems Mission Directorate, NASA Headquarters**





To reach for new heights and reveal the unknown, so that what we do and learn will benefit all humankind.

## **NASA Strategic Goals**

1. Extend and sustain human activities across the solar system.
2. Expand scientific understanding of the Earth and the universe in which we live.
3. Create the innovative new space technologies for our exploration, science, and economic future.
4. Advance aeronautics research for societal benefit.
5. Enable program and institutional capabilities to conduct NASA's aeronautics and space activities.
6. Share NASA with the public, educators, and students to provide opportunities to participate in our Mission, foster innovation, and contribute to a strong national economy.

# A New Path: The NASA Authorization Act of 2010



- **The Congress approved and the President signed the National Aeronautics and Space Administration Authorization Act of 2010**
  - Bipartisan support for human exploration beyond Low Earth Orbit
- **The law authorizes:**
  - Extension of the International Space Station until at least 2020
  - Strong support for a commercial space transportation industry
  - Development of a multi-purpose Crew Vehicle and heavy lift launch capabilities
  - A “flexible path” approach to space exploration opening up vast opportunities including near-Earth asteroids (NEA) and Mars
  - New space technology investments to increase the capabilities beyond low Earth orbit



1. Human adaptation to space produces physiological changes similar to some experienced by disabled and aging people on Earth. What shared knowledge exists between disability/rehabilitation research and NASA research? Are there gaps, duplications, and synergies?
2. What has NASA learned from human spaceflight that might be applied to the general population of individuals with disabilities? What areas might be recommended for further study with respect to disability?
3. What is the status of knowledge and technology transfer from space flight experience to individuals with disabilities?
4. How can we leverage space flight knowledge? What is the connection between the NASA knowledge base on astronauts and the state of the science in disability and rehabilitation research? Is there a need for a research partnership? Is more knowledge and tech transfer needed or recommended? Is there an existing or emerging partnership opportunity?

Basic notions of space flight exercise need and problems due to things that happen as a human adapts to space flight.

- Humans “float”, commonly called weightlessness. The body is “unloaded”, no longer needing to resist the pull of gravity. Therefore, NASA needs to replace the foot-ward force of gravity – Springs, Elastic cords, LBNP in space, LBPP on ground can be used on ground to simulate unloading.
- Reflexes that cause pressure gradients in peripheral leg blood vessels to resist gravity-driven blood pooling in the lower legs cause a fluid-shift to the upper body. Eventually, reflexes redistribute fluid and excess is eliminated.
- With 2 week to 6 month adaptation to space, anti-gravity muscles weaken, bones lose calcium and density, reflexes (cardiovascular, vestibular, etc) adapt to perform their control functions in the new environment.
- Vertical treadmill on Earth enables prone or supine use by subject to simulate space acutely or in bed rest subjects.
- NASA flight hardware places premium on design safety and ease of use in addition to efficacy

Illustrated by: Hargens lab LBNP/LBPP Treadmill video

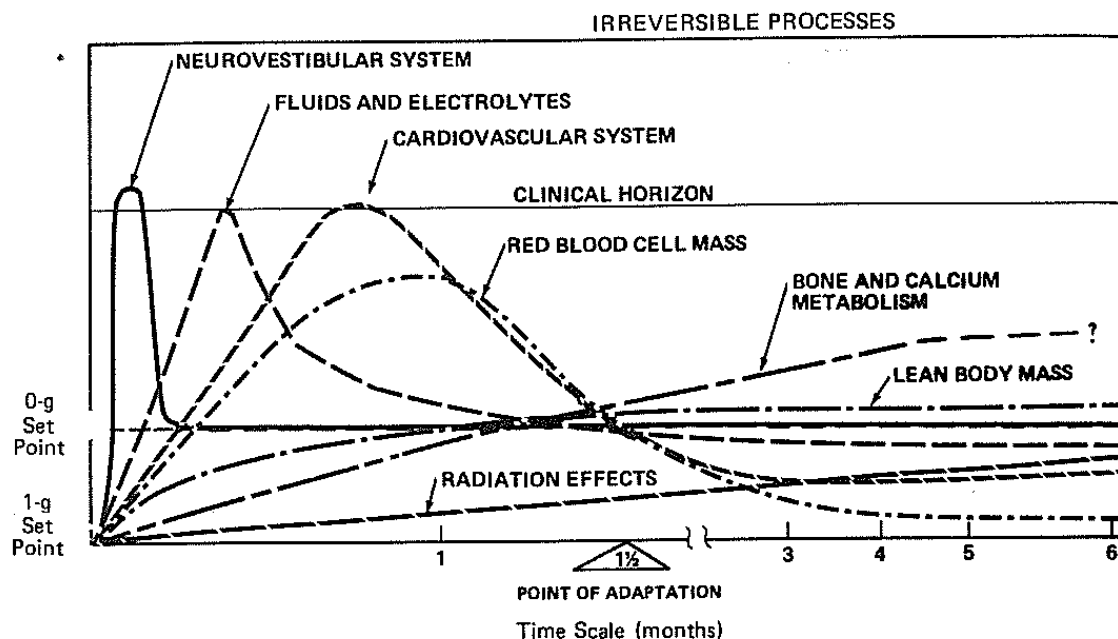
[http://www.youtube.com/watch?v=f-k2gWhkQeU&feature=player\\_embedded](http://www.youtube.com/watch?v=f-k2gWhkQeU&feature=player_embedded)

# Physiological Adaptation to Space Flight



148

## PHYSIOLOGICAL ADAPTATION TO SPACE FLIGHT



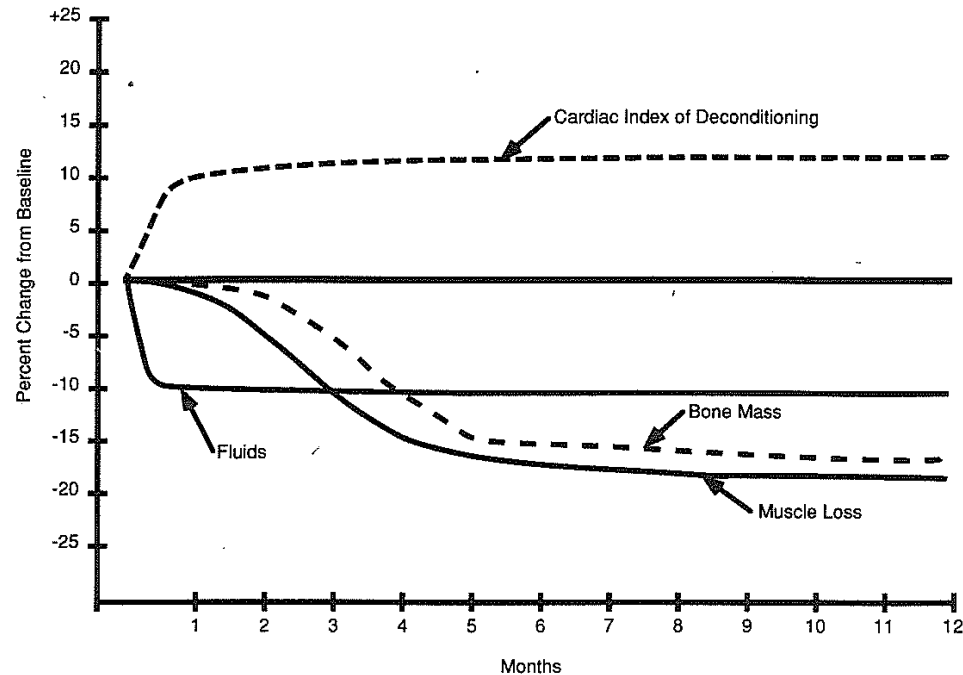
**Figure 7-1.** Time course of physiological shifts associated with acclimation to weightlessness. 1-g set point represents physiological status on Earth. 0-g set point denotes a complete physiological adaptation level in space, which probably can only be achieved by individuals born in space. Point of adaptation is the average time of 6 weeks required for a visitor to space to exhibit partial adaptation to the environment.

FROM: Space Physiology and Medicine. NASA SP-447, by Arnauld Nicogossian, M.D. and James F. Parker, Ph.D., 324 pages, published by NASA, Washington, D.C., 1982

# Overall Physiologic Response to Space Flight



OVERALL PHYSIOLOGIC RESPONSE TO SPACE FLIGHT 215



**Figure 11-1.** The time course of some of the physiologic shifts associated with acclimation to weightlessness. The horizontal line at zero represents physiologic status on Earth. The greatest change from baseline is thought to occur after 4 to 6 months in space. Cardiovascular function and body fluid levels change within hours of exposure to weightlessness. The cardiac index of deconditioning indicates severity of orthostatic intolerance exhibited by crewmembers subjected to gravitational stress.

FROM: Space Physiology and Medicine. by A.E. Nicogossian, Huntoon, C.L., and Pool, S.L., published by Lea & Febinger, Philadelphia, 1994.





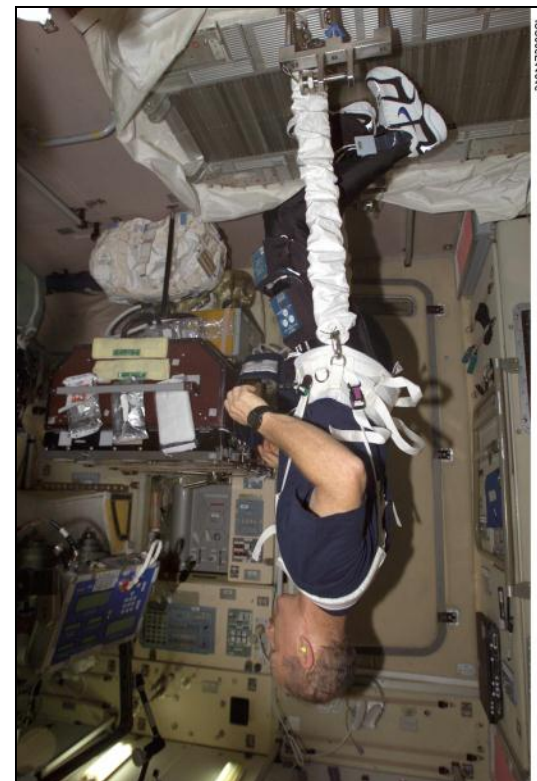
# **NASA Human Exercise Hardware and Technology Transfer**



# Exercise as Countermeasure on ISS



- Exercise is a potential solution for many of the health problems encountered in space
  - Psychological benefits
    - Antidepressant, relieves stress, better sleep
  - Physical fitness benefits
    - Aerobic capacity
    - Cardiovascular system
    - Muscle mass and bone strength



***Lack of gravity  
requires exercise  
hardware to  
maintain baseline  
physical fitness***

# Space Flight Treadmill



Monitoring and measuring performance – cardiopulmonary monitors, foot forces, forces produced (typically user specified) – For example:  
[http://case.academia.edu/KerimGenc/Papers/267693/Foot\\_forces\\_during\\_exercise\\_on\\_the\\_International\\_Space\\_Station](http://case.academia.edu/KerimGenc/Papers/267693/Foot_forces_during_exercise_on_the_International_Space_Station)

# Space Flight Treadmill Kinematics Experiment

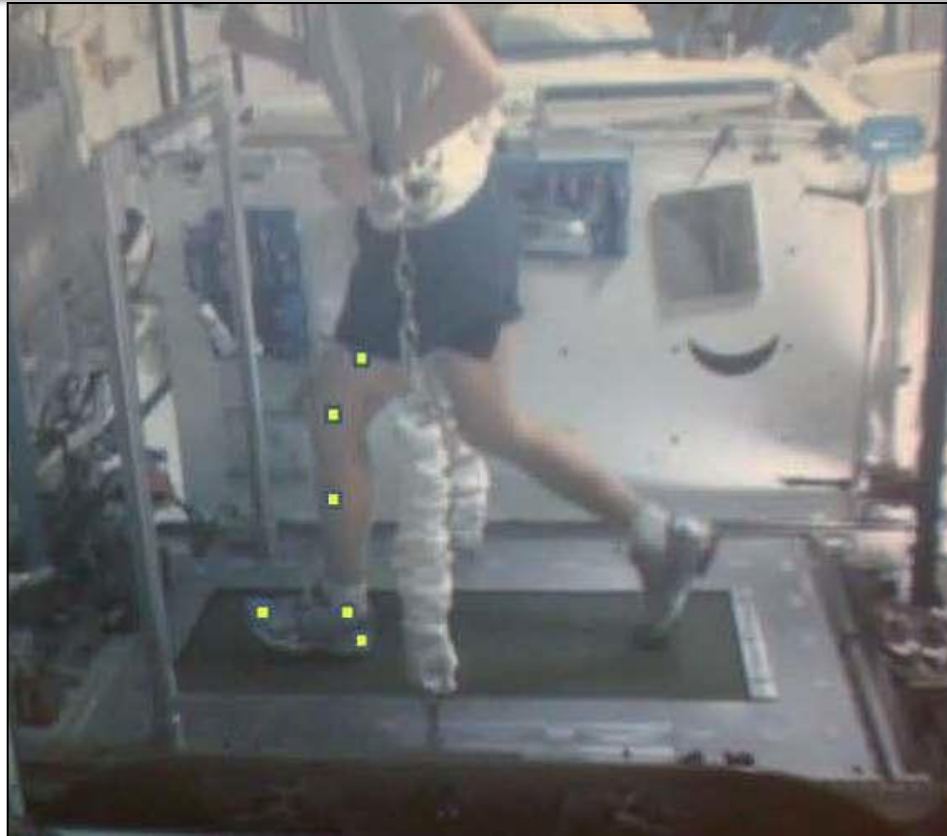
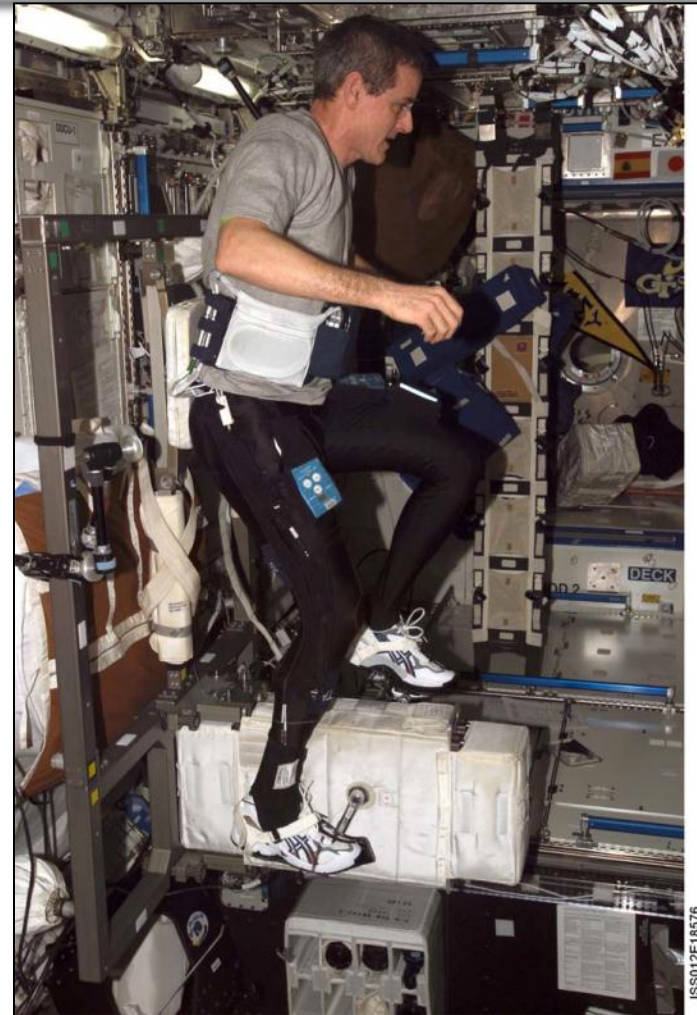


Image taken from video capture of a Treadmill Kinematics session in Node 3 aboard the ISS shows marker locations and the attachment point of the bungee system to the surface. These items are important for the analysis performed by the investigation.

[http://www.nasa.gov/mission\\_pages/station/research/experiments/Treadmill\\_Kinematics.html](http://www.nasa.gov/mission_pages/station/research/experiments/Treadmill_Kinematics.html)



# Space Flight Cycle Ergometer



Descriptions of exercise devices and medical monitoring equipment

[http://lsda.jsc.nasa.gov/llda\\_data/mrid\\_docs/CHeCSHWMaster.pdf](http://lsda.jsc.nasa.gov/llda_data/mrid_docs/CHeCSHWMaster.pdf)



- **Cycle Ergometer with Vibration Isolation & Stabilization (CEVIS)**  
provides aerobic and cardiovascular conditioning through cycling. CEVIS can be used for either leg or arm ergometry. The Arm Handle and Pedal Crank assemblies are attached with identical interfaces and can be changed out during an exercise session by a crewmember.
- Exercise sessions and protocols stored on memory cards.
- Control panel can display:
  - Cycling speed and deviation from target speed
  - Elapsed Time
  - Target and actual Workload
  - Target and actual heart rate

# Space Flight Resistive Exercise



- Resistive Exercise Devices (RED) are designed and used to maintain muscle and bone strength and endurance during space flight. Simulates free weights.



# Space Flight Resistive Exercise



(Left) (10 April 2010) --- NASA astronaut Alan Poindexter, STS-131 commander, exercises using the advanced Resistive Exercise Device (aRED) in the Tranquility node of the International Space Station while space shuttle Discovery remains docked with the station.

<http://spaceflight.nasa.gov/gallery/images/station/crew-23/html/s131e008532.html>





**Advanced Resistive Exercise Device (ARED)** – device used to maintain muscle & bone strength and endurance. Simulates free weights using constant and inertial loads.

- Lift Bar loads range from 0 to 600 lb. The Exercise Rope can provide up to 150 lb of load, and a maximum 72” stroke.
- Crewmembers perform Exercise Rope and Lift Bar exercises to strengthen all major muscle groups.
  - They use deadlifts, bent over rows, bicep curls, bench presses, shoulder presses, shoulder raises, squats, and heel raises.
- A touch screen display allows a crew member to find and select a personal prescription. Software stores performance information for later download.



# Space Flight Exercise Technology Spin-offs

# Resistive Exercise Device “Flex Pack”





SpiraFlex® is a revolutionary new patented technology for storing and delivering mechanical power in industrial, consumer, and fitness equipment. Kansas City-based SpiraFlex, Inc., invented and supplied this technology for use on the International Space Station, with assistance from Wyle Laboratories of Houston, Texas, and NASA's Johnson Space Center. NASA research facilities and funding helped to develop the Resistance Exercise Device (RED), powered by SpiraFlex. The RED system is used by ISS crewmembers as a countermeasure against musculoskeletal degradation caused by microgravity. It uses elastomer compounds molded into a range of patented shapes called FlexPacks™ which create unique torsional resistance properties. These FlexPacks may operate alone, or linked in parallel or a series to output devices that allow almost any force curve to be achieved by manipulating the FlexPack and output device characteristics.

The RiPP Strength Training machine is compact and easy to use.

This technology provides a variety of benefits for anyone seeking a well-crafted, high-grade, strength-training machine. One of the most attractive benefits is that the unit is lightweight and portable. SpiraFlex technology is inexpensively manufactured, easily assembled, and quietly operated because no metal parts are used. Recognizing these benefits, and using SpiraFlex technology, Schwinn Cycling & Fitness, Inc., of Boulder, Colorado, launched an international fitness program for health clubs and select retail distributors, called RiPP™ (Resistance Performance Program). RiPP is an exercise program that uses RiPP Pro machines, powered by SpiraFlex technology. The program generally consists of a 45-minute resistance-training session, taught by a certified RiPP Coach, that offers participants a motivational group exercise atmosphere.

SpiraFlex® technology, FlexPack™ and RiPP™ are registered trademarks of SpiraFlex, Inc.

- **Work at Glenn Research Center and Cleveland Clinic**
- Enables simulation of the skeletal unloading experienced in spaceflight
- Enables locomotion either for exercise or for research in immobilized humans in prone or supine positions.
- For example NASA uses bed rest subjects maintained in a 6 degree head-down tilt to simulate the fluid shifts, as well as bone and muscle atrophy seen in space flight.
- Applicability as a potential clinical tool is obvious.

Illustrated by: Cavanagh Lab Video

<http://www.youtube.com/watch?v=bfYucYAWnvE&NR=1>



- **Rehabilitation research from NASA Ames and UCSF**
- Based on research conducted at NASA Ames Research Center by Dr. Alan Hargens and Dr. Robert Whalen (patent holders) in the 1980's and 1990's
- NASA needed to simulate Earth gravity (g) in space, and partial gravity (e.g., moon or Mars in space or during bed rest)
- Concept: lower body is in chamber sealed at the waist; chamber placed either at reduced pressure to simulate Earth g, or elevated pressure to simulate reduced g.
- Device has been used clinically in rehabilitation research as illustrated in the videos.

Illustrated by video: AlterG Whalen Spin-off

<http://www.alter-g.com/rehabilitation-equipment>

<http://www.alter-g.com/product/anti-gravity-treadmills>

<http://www.youtube.com/watch?v=XIH4hnODGNE&feature=related>

# EDGERTON LABORATORY AT UCLA BRAIN RESEARCH INSTITUTE: LEVERAGING SPACE FLIGHT KNOWLEDGE TO CONTRIBUTE TO UNDERSTANDING AND IMPROVING PLASTICITY OF SPINAL CORD INJURY



- Edgerton VR, Roy RR, Hodgson JA, Day MK, Weiss J, Harkema SJ, Dobkin B, Garfinkel A, Konigsberg E and Koslovskaya I (2000). How the science and engineering of spaceflight contribute to understanding the plasticity of spinal cord injury. *Acta Astronaut.* 47 (1): 51-62.
- **Summary:** Space programs support experimental investigations related to the unique environment of space and to the technological developments from many disciplines of both science and engineering that contribute to space studies. Furthermore, interactions between scientists, engineers and administrators, that are necessary for the success of any science mission in space, promote interdiscipline communication, understanding and interests which extend well beyond a specific mission. NASA-catalyzed collaborations have benefited the spinal cord rehabilitation program at UCLA in fundamental science and in the application of expertise and technologies originally developed for the space program. Examples of these benefits include:
  1. better understanding of the role of load in maintaining healthy muscle and motor function, resulting in a spinal cord injury (SCI) rehabilitation program based on muscle/limb loading;
  2. investigation of a potentially novel growth factor affected by spaceflight which may help regulate muscle mass;
  3. development of implantable sensors, electronics and software to monitor and analyze long-term muscle activity in unrestrained subjects;
  4. development of hardware to assist therapies applied to SCI patients; and
  5. development of computer models to simulate stepping which will be used to investigate the effects of neurological deficits (muscle weakness or inappropriate activation) and to evaluate therapies to correct these deficiencies.
- Brain Research Institute, University of California, Los Angeles, USA.



# Common physiological problems of humans who fly in space, age, or are physically disabled



- Osteoporosis and Increased Bone Fracture Risk
- Loss of Muscle Mass and Resultant Loss of Strength
- Changes in Balance and Gait Control Due to Balance Organ and Nervous System Changes
- Orthostatic Hypotension Due to Any of a Number of Factors, Ranging from Changes in Fluid Balance Throughout the Body to Neural Changes.
  - The decrease of blood pressure while standing upright may lead to fainting, falls and thus injuries
- Impaired Nutrition and Vitamin D Metabolism
- Changes in Immunological Response Competence



- **Orthopedic implant decontamination**

- NASA research on low Earth orbital atomic oxygen and materials testing developed a process for removal of biologically active contaminants from surfaces of orthopedic implants.
- Most orthopedic implants have endotoxins on their surfaces that cause inflammation and pain. Such responses can lead to joint loosening and implant failure. Implant surface exposure to atomic oxygen has been demonstrated to fully remove all endotoxins, thus minimizing chances of inflammation after surgery.

- **Biomedical Wireless and Ambulatory Telemetry for Crew Health (BioWATCH)**

- Wireless biometric monitoring system originally designed to monitor astronaut health in space can measure heart rate, blood pressure, glucose, temperature, joint angle, ECG, and blood oxygenation, and then send the information to doctors on Earth in real time.
- Commercial version of BioWATCH transmits data to doctors wirelessly via cell phone, wireless internet or Bluetooth. It can be configured to monitor various conditions, which makes it ideal for post-surgery patients, participants in clinical drug trials, and home healthcare patients.

- **Remote Medical Capability Enhancements**

- Ultrasound has been utilized as a non-invasive imaging tool, and NASA researchers and the medical community continue to expand the capability to use this tool for telemedicine assessment and enhanced care delivery.
- NASA supported efforts developing procedures and training for remote guided ultrasound has increased the utility of this technique for potential use in emergency vehicles, rural care, assisted living facilities, military conflicts, and third world medicine on Earth.

# Answers to the organized questions



1. Human adaptation to space produces physiological changes similar to those experienced by disabled and aging people on Earth. What shared knowledge exists between disability/rehabilitation research and NASA research? Are there gaps, duplications, and synergies?
2. What has NASA learned from human spaceflight that might be applied to the general population of individuals with disabilities? What areas might be recommended for further study with respect to disability?
3. What is the status of knowledge and technology transfer from space flight experience to individuals with disabilities?
4. How can we leverage space flight knowledge? What is the connection between the NASA knowledge base on astronauts and the state of the science in disability and rehabilitation research? Is there a need for a research partnership? Is more knowledge and tech transfer needed or recommended? Is there an existing or emerging partnership opportunity?

# Web Sites and Contact Information



- Hargens lab LBNP/LBPP Treadmill video  
[http://www.youtube.com/watch?v=f-k2gWhkQeU&feature=player\\_embedded](http://www.youtube.com/watch?v=f-k2gWhkQeU&feature=player_embedded)
- Cavanagh Lab Video  
<http://www.youtube.com/watch?v=bfYucYAWnvE&NR=1>
- AlterG Whalen Spin-off  
<http://www.alter-g.com/rehabilitation-equipment>  
<http://www.youtube.com/watch?v=XIH4hnODGNE&feature=related>
- Crew Health Care System contains detailed descriptions of aRED, CEVIS, TVIS and medical monitoring equipment  
[http://lsda.jsc.nasa.gov/lsda\\_data/mrid\\_docs/CHeCSHWMaster.pdf](http://lsda.jsc.nasa.gov/lsda_data/mrid_docs/CHeCSHWMaster.pdf)

David Tomko – [dtomko@nasa.gov](mailto:dtomko@nasa.gov) 202-358-2211